International Journal of Physiotherapy and Research,
Int J Physiother Res 2015, Vol 3(4):1156-62. ISSN 2321-1822
DOI: http://dx.doi.org/10.16965/ijpr.2015.160

Original Article

LOAD EQUIVALENCE OF TRANSIENT DEFORMATION CHARACTERISTICS OF EXERCISE ELASTIC TUBES USED IN PHYSIOTHERAPY REHABILITATION AND FITNESS TRAINING PROGRAMS

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ABSTRACT

Introduction: Exercise elastic tubes (EET) have been used in Fitness training and Physiotherapy rehabilitation programs. Although we have practically felt the behavior of different levels of elastic resistance devices but the exact amount of opposing force they produce are not well understood, hence this lack of knowledge can reduce the quality of exercise prescriptions. Based on the findings of simple experiments done with EET, this article unfolds the scope for inexpensively studying the load equivalence (in kilograms) of different levels of EET for refined physiotherapy rehabilitation and fitness training practices.

Materials and Methods: The objective of this experiment was to understand the lengthening and thickness deformation behavior of EET using different loads so that the load equivalency of a particular elongation or lengthening effect can be used in refining the exercise prescription standards. The changes in length of EET were measured using inch tape whilst the changes in thickness of EET were measured using the vernier caliper.

Results: The data of transient deformation of LEVEL-3 and LEVEL-5 EET in different feasible loading conditions shows strong negative correlation between the thickness and length of EET. The doubling of the original length was obtained with 7.5 Kg load for LEVEL-3 EET and 15 Kg load for LEVEL-5 EET which reflects their resistance level (modulus of elasticity) designed for appropriate strength training programs. Another innovative experiment was also conducted in which two LEVEL-3 EET were subjected together as a composite unit and their response to different loads was also observed and hypothesized as possible behavior of Level-6 EET.

Discussion: The results obviously gives the load equivalence features in kilograms for particular level of elongation of EET instead of merely selecting and applying different levels of EET without knowing how much resistive force they can afford for strength training purposes.

Conclusion: Though an inexpensive method of discovering the load equivalence of EET was discussed throughout this article, a furthermore safe and sophisticated laboratory to test all available levels of EET is strongly recommended because, if the loaded elastic material ruptures it can sabotage anything around it.

KEY WORDS: Elastic Tubes, Resistance Bands, Load Equivalence, Thickness And Elongation Of Elastic Tubes, Elastic Resistance Exercise.

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Quick Response code	International Journal of Physiotherapy and Research ISSN 2321- 1822 www.ijmhr.org/ijpr.html	
DOI: 10.16965/ijpr.2015.160	Received: 18-06-2015 Peer Review: 18-06-2015 Revised: None	Accepted : 13-07-2015 Published (O): 11-08-2015 Published (P): 11-08-2015

INTRODUCTION

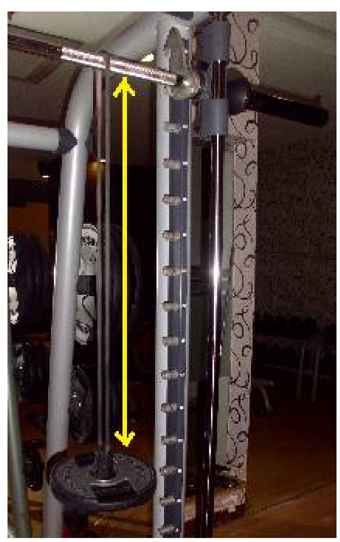
Exercise elastic tubes (EET) have been commonly used in Fitness training and Physiotherapy rehabilitation programs. Elastic tubing could be an inexpensive alternative for people who want to perform strength training but do not have access to more expensive or sophisticated equipment [1]. Joseph B Myers et al recommen-

-ded seven resistance exercises with rubber tube as pre-throwing warm up routines for throwers [2]. Elastic bands are frequently used for resistance training; however the selection of the bands to progress through the levels of elastic resistance is done in a subjective manner due to the lack of quantitative data on the value of the material's resistance as a function of its tension [3]. Mechanical tests done by Martins WR et al revealed different elastic forces for different levels of elongation of each tube and recommended for the replication of the results in clinical situations, so the elastic resistance in clinical routine could be evaluated with more propriety [4]. The prediction of maximum tension values of elastic tubing for any given elongation is possible by simple variation of resting length [5]. Although we have practically felt the behavior of different levels of elastic resistance devices but the exact amount of opposing force they produce are not well understood, hence this lack of knowledge can reduce the quality of exercise prescriptions. Based on the findings of simple experiments done with EET, this article unfolds the scope for inexpensively studying the load equivalence (in kilograms) of different levels of EET for refined physiotherapy rehabilitation and fitness training practices.

METERIALS AND METHODS

The objective of this experiment was to understand the lengthening and thickness deformation behavior of EET using different loads in a readily available non-laboratory set up, so that the load equivalency (in kilograms) of a particular elongation or lengthening effect can be used in refining the exercise prescription standards. The term non-laboratory set up indicates the gym environment which was not intended to do such experiments but the analysis had to be carried out with minimum available resources and continual creativity, at par with safety precautions because, if the loaded elastic material ruptures it can sabotage anything around it. The minimum resources opted to conduct this experiment was (a) Level-3 exercise elastic tube (b) Level -5 exercise elastic tube (c) Inch tape (d) Vernier caliper (e) Technogym barbell plates - 2.5 Kg, 5 Kg, 10 Kg and some additional loads if required in this same range and (f) Supporting bar to secure the EET, so smith machine was found suitable.

The EET was made double its length by forming a loop around the supporting bar and the required load was applied on the handles of the EET which is named as *Looped loading experiment*. As expected, increase in the length and decrease in the thickness (or diameter) of EET was noticeable under loading conditions. The changes in length were measured using inch tape in the vertical portion of the EET (Photograph-1) and the changes in thickness were measured using the vernier caliper (Photograph-2). A semicircular area of EET hooking on to the supporting bar (SB) was consistently found to be 7 cm long (Figure-1) but for simplicity, only the changing dimensions in the vertical portion of EET was observed and measured. Figure-2 schematically shows lengthening and thinning effect on the EET in different loading conditions with the SB located at 195 cm above the ground level, so the experiment had to be conducted within this vertical limit. After making a loop around the SB, the handles of the EET were passed through the central opening of the barbell plates (Photograph-3) which normally gives a facility to effectively secure the load to stress and elongate this elastic tube. The length and thickness of the Level - 3 and Level-5 EET at rest and loaded conditions (2.5 Kg, 5 Kg, 7.5 Kg, 10 Kg and 12.5 Kg) were measured and compared. In fact, because of the higher material stiffness, Level-5 EET could be additionally tested with 15 Kg, 17.5 Kg and 20 Kg. The original dimension of Level-3 and Level-5 EET at rest

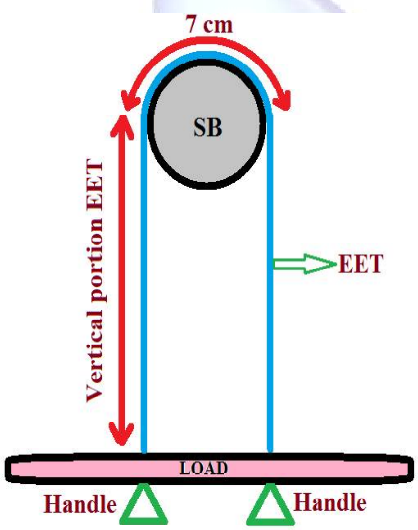


Photograph 1: The vertical portion of looped EET was measured using inch tape for under-standing the magnitudeof elongation under different loading conditions as compared to its length at rest.

after getting looped around the supporting bar was 55 cm long with 10.1 mm thickness and 62 cm with 10.3 mm thickness, respectively, and both these elastic tubes were able to regain their original dimension between all loading experiments (Photograph-4, 5 & 6).

Photograph 2: The thickness (diameter) of looped EET was measured using vernier caliper under different loading conditions as compared to its original thickness at rest.

Fig. 1: Schematic side view of the experimental set up with the EET under loading with a barbell plate. A semi-circular area of EET of about 7 cm was constantly found wrapping the upper and side portions of SB but this portion was found completely flattened and thinned under loading conditions. The diameter of the supporting bar was 2.8 cm.

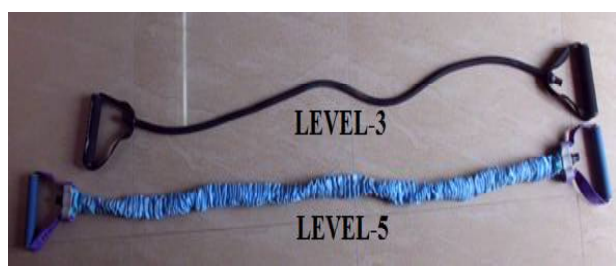


Photograph 3: Shows the facility to secure the barbell plate by passing the handles of the EET through its central opening.

Photograph 4: Shows the LEVEL-3 EET (Brand name - CHAMP) and the LEVEL-5 EET (Brand name - Reebok). The thickness or diameter of LEVEL -3 EET at rest was 10.1 mm and of LEVEL-5 EET at rest was 10.3 mm.

Level 3 FET **Level 4 FET**

Photograph 5: Shows the total length of the elastic portions of LEVEL-3 EET (115 cm) at rest and the LEVEL-5 EET (132 cm) at rest. After getting looped around the SB, at rest LEVEL -3 EET was 55 cm long with 10.1 mm thickness and LEVEL-5 EET 62 cm with 10.3 mm thickness.



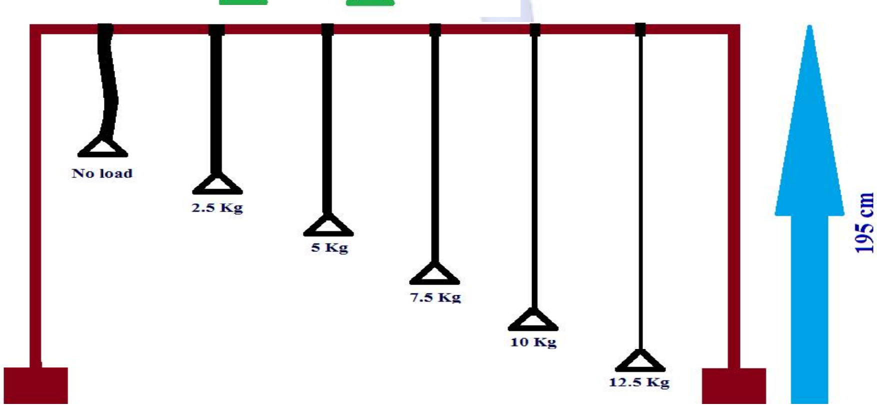


Fig 2: Schematically shows the observable characteristics of EET in different loading conditions. The supporting bar was located at 195 cm from the ground level and this had set a vertical limit to conduct the study with further higher loads. It should be noted here, that this is just a schematic representation of the EET's behavior not the experimental set up with serially arranged EET.

Photograph 6: Shows the thickness of the elastic portions of LEVEL-3 EET (2.5 mm excluding the tubular portion) at rest and the LEVEL-5 EET (4.5 mm excluding the tubular portion) at rest. But this thickness could not be measured during loading conditions though it must have undergone principal changes to decrease the diameter and increase the length of the EET.

(a) (b)

RESULTS AND TABLES

The data of transient deformation of LEVEL-3 and LEVEL-5 EET in different feasible loading conditions can be found in table-1 & 2. The inverse relationship between the thickness and length of EET under loading conditions is also made evident. In the looped loading experiment, the doubling of the original length of EET was obtained with 7.5 Kg load for LEVEL-3 EET and 15 Kg load for LEVEL-5 EET which reflects their resistance level (modulus of elasticity) designed for appropriate strength training programs. Another innovative experiment was also conducted in which two LEVEL-3 EET were subjected together as a composite unit (by passing all 4 handles through the central opening of a single barbell plate) and their possible behavior as Level-6 EET to different loads can be found in table-3. Comparison graphs 1, 2 & 3 displays the transient deformation characteristics of EET in all these three major experiments.

Table 1: (LOOPED LOADING EXPERIMENT: 1) Elongation and thickness characteristics of LEVEL-3 EET under different loading conditions. There is a strong negative correlation between thickness and maximum elongation (r = - 0.9912)

Status of the EET	Load (Kg)	Thickness (mm)	Maximum elongation (cm)	Length gain (cm)
At rest	-	10.1	55	-
Under tension	2.5	10	64.5	9.5
Under tension	5	9	81	26
Under tension	7.5	8	104	49
Under tension	10	7	140	85
Under tension	12.5	6	175	120

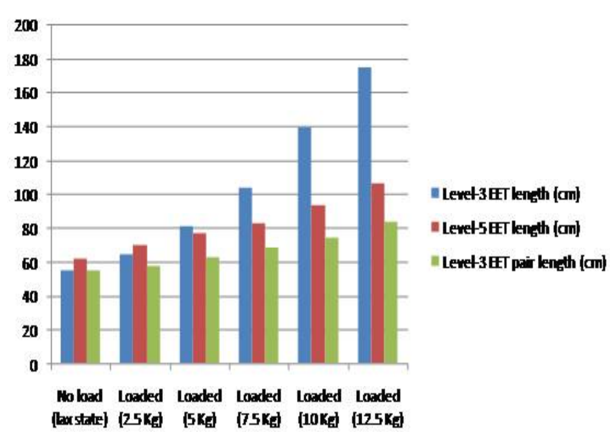
Table 2: (LOOPED LOADING EXPERIMENT: 2) Elongation and thickness characteristics of LEVEL-5 EET under different loading conditions. There is a strong negative correlation between thickness and maximum elongation (r = - 0.9772).

Status of the EET	Load (Kg)	Thickness (mm)	Maximum elongation (cm)	Length gain (cm)
At rest	-	10.3	62	-
Under tension	2.5	10.2	70	8
Under tension	5	10.2	77	15
Under tension	7.5	10.1	83	21
Under tension	10	10	94	32
Under tension	12.5	9	107	45
Under tension	15	8.5	125	63
Under tension	17.5	7.5	140	78
Under tension	20	7	164	102

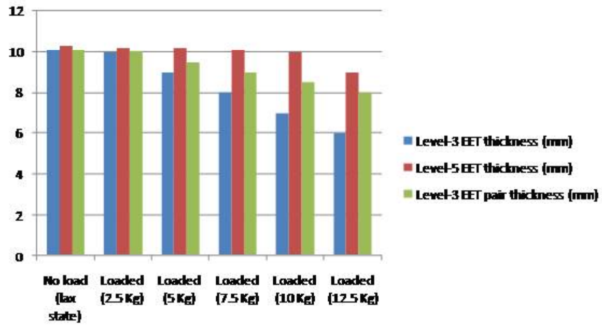
Table 3: (LOOPED LOADING EXPERIMENT: 3) Elongation and thickness characteristics of possible LEVEL-6 EET (two LEVEL-3 EET were subjected together as a composite unit) under different loading conditions. There is a strong negative correlation between thickness and maximum elongation (r = - 0.9783). Such composite arrangement of two elastic tubes can be used for obtaining greater resistances to strength training for suitable individuals, in the absence of higher level EET.

Status of the EET	Load (Kg)	Thickness (mm)	Maximum elongation (cm)	Length gain (cm)
At rest	-	10.1	55	-
Under tension	2.5	10.05	58	3
Under tension	5	9.5	63	8
Under tension	7.5	9	69	14
Under tension	10	8.5	75	20
Under tension	12.5	8	84	29
Under tension	15	7.5	99	44
Under tension	17.5	7	114	59
Under tension	20	6.5	127	72

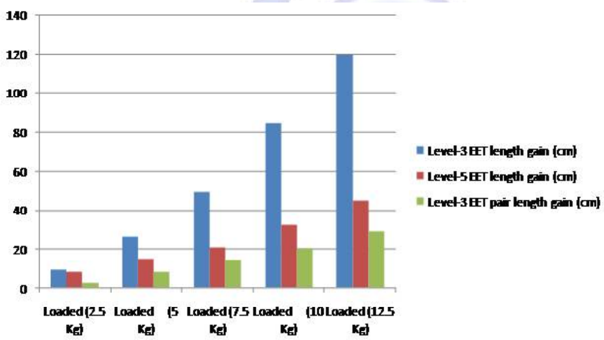
Graph 1: The maximum elongated length of EET at rest and during different loading conditions.



Graph 2: The thickness of EET at rest and during different loading conditions.



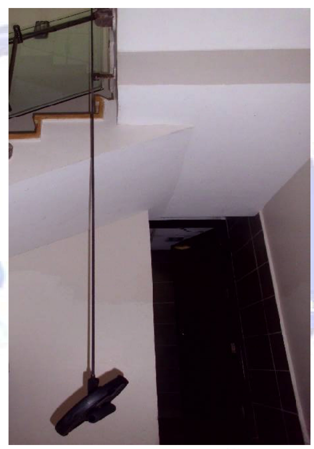
Graph 3: The length gains of EET at rest and during different loading conditions.



DISCUSSION

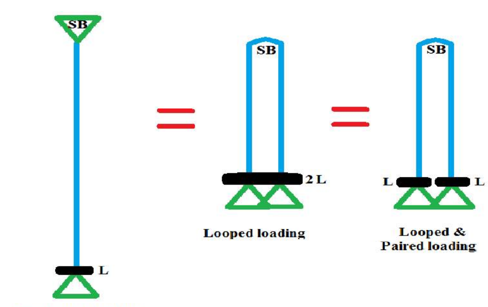
These results obviously gives the load equivalence features in kilograms for particular level of elongation of EET instead of merely selecting and applying different levels of EET without knowing how much resistive force they can afford for strength training purposes. Although not discussed in detail, during these three major experiments, other modified experiments were also done (Photograph - 7, 8 & Figure-3). The vertical limit (Figure-2) and extension of the experiments with higher loads by stacking more than one load (Photograph-9) were the factors posing difficulties during this experiment; hence further improvisation in creating a safe, inexpensive and experiment-friendly atmosphere is warranted.

Photograph 7: This is non-looped loading but it poses practical difficulties in doing experiments with higher loads as the maximum elongation requires enough space and measurable atmosphere. The transient deformation characteristics of EET in this experiment was found to be equal to the effect caused by just one load in the looped loading experiments discussed earlier and the experiment discussed in Photograph-8 . For example, the effects of 2.5 Kg load in non-looped loading was equal to the effect caused by (a) looped loading with 2.5 Kg loads for each handles and (b) looped loading with a 5 Kg load hooked commonly to both handles. The maximum elongation of EET in non-looped loading is almost equal to the sum of maximum elongation of EET on both the sides in looped loading. To be clearer, the maximum elongation of LEVEL-3 EET in non-looped loading with 2.5 Kg was 166 cm but in looped-loading the maximum elongation on both sides was 81 cm (81 cm + 81 cm = 162 cm) excluding the length of semicircular portion of EET, so equal deformation effects of all the three different techniques was observed.



Photograph 7

Fig. 3: Equal effect possibilities with non-looped loading, looped loading and looped-paired loading. The transient deformation effects caused by load (L) in non-looped loading can be found equal in looped loading if (i) the load (L) is doubled and applied as a single load (2L) and (ii) as paired loading (L & L).

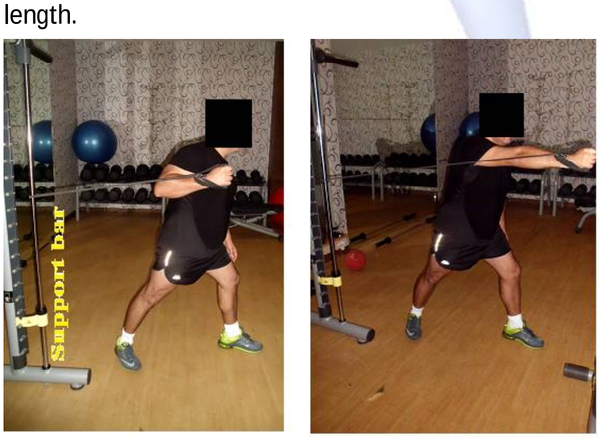


Photograph 8: Looped and paired loading with two similar loads hooked to the handles separately. (Relate photograph-7 and figure-3).

Photograph 9: Stacking additional loads and experimenting furthermore is interesting but requires manual effort and gradual incremental loading techniques to avoid any injurious consequences caused by rupturing of the EET. Actually this was a single-handed experiment which demanded patience and appropriate energy levels while conducting all these experiments.

The purpose of this study is to relate the load equivalence with dimensions of the EET for practical applications in all the exercise techniques performed with EET. For instance, the individual shown in the photograph- 10 performed single arm chest press with static forward lunge with LEVEL-3 EET looped around a vertical beam. The length of this EET at the starting position and finish position was 82 cm and 146 cm, respectively. Based on table-1, the 82 cm elongation is equal to 5 Kg load and 146 cm elongation is equal to 10 Kg load approximately, which means he had to impart muscular force in the range of 5 - 10 Kg. This is how load equivalence can be figured out for changing dimensions of EET during exercise. If this same task should be decreased or increased in intensity, then the standing position of the exerciser can be moved closer to or farther from the support bar, respectively. The force of elastic resistance depends on percentage of elongation, regardless of initial length and typical clinical elongations rarely exceed 200 % [6].

Photograph 10: This technique is called single arm chest press with static lunge posture using LEVEL-3 EET and when this individual was performing this technique (a) the start position brought the length of EET to 82 cm and (b) the finish position brought the length of EET to 146 cm. Based on table-1, the 82 cm = 5 Kg and 146 cm = 10 Kg, approximately. This EET elongation is also highly individual-specific based on the muscular strength and anthropometric characteristics like upper extremity length.



(a) (b)

The importance of EET in the field of exercise is well established. "Both elastic resistance and free-weight resistance (such as barbells and dumbbells) have several similar properties: (a) both provide some form of resistance, (b) both allow a free range of motion, (c) both allow variable speed of movement, and (d) both allow progressive resistance and all four of these properties are critical for the benefits offered by effective resistance-training programs. With elastic tubing, on the other hand, you can have resistance when doing exercises in a horizontal plane" [7]. Valid exercise innovations for shoulder joint using resistance bands, medicine ball, free weights and strength training machines will happen by understanding the humeral head spinning styles [8]. Home-based resistance training programs utilizing elastic tubing can serve as a practical and effective means of eliciting strength gains in adults over the age of 65 [9]. Further research works on the basis of these experimental findings can lead to next level standardization of exercise prescriptions with EET.

CONCLUSION

Though an inexpensive method of discovering the load equivalence of EET was discussed throughout this article, a furthermore safe and sophisticated laboratory to test all available levels of EET is strongly recommended. The whole experiment was done on the support bar whose diameter was 2.8 cm so the behavior of the EET used in this study on a different support bar with higher or lesser diameter than 2.8 cm is yet to be explored. Possibilities are there that the EET of same category may respond slightly different to same loads. Periodic re-evaluation of the EET on the basis of the looped or non-looped loading experiments in clinical and fitness training set ups may reveal any permanent alterations in its dimensions caused by over usage and impending risk of damage. In fact, this sort of experiments must be pursued in the undergraduate level of Physiotherapy for scientific utilization of exercise elastic tubes in Physiotherapy rehabilitation and Fitness training programs. If load equivalence and transient deformation characteristics of EET are known, then deriving particular load equivalence and exercise intensity from EET can be regulated by exercise postures, training purpose, fitness level and anthropometric features of individuals (like upper extremity length).

Conflicts of interest: None

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How to cite this article:

R.Vinodh Rajkumar. LOAD EQUIVALENCE OF TRANSIENT DEFORMATION CHARACTERISTICS OF EXERCISE ELASTIC TUBES USED IN PHYSIOTHERAPY REHABILITATION AND FITNESS TRAINING PROGRAMS. Int J Physiother Res 2015;3(4):1156-1162. **DOI:** 10.16965/ijpr.2015.160